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Book of Abstracts
November 2-5, 1998

Kellie Ann Beall, Editor

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Gaithersburg, Maryland 20899

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LARGE-SCALE PLANAR MEASUREMENTS AND SCALING OF SPRINKLER SPRAYS

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INTRODUCTION

Water spray sprinklers are the most commonly used automatic fire protection systems in buildings ranging from small offices to large warehouses. For effective fire suppression, the sprinkler water must reach the burning surface. An optimum sprinkler system, for a given application, is one that providesthe maximum fraction of water delivered by the sprinkler (or sprinklers in a large warehouse) to the burning surfaces and suppresses the fire in the shortest time after its initiation. The design of such a sprinkler system depends on the geometrical relationship between the sprinkler(s) andthe fire source and its heat release rate, the geometry of the room and its ventilation conditions and the sprinkler spraycharacteristics. Given the complexity of the problem, the optimization, as well as the evaluation, of various sprinkler systems ismost cost-effectively accomplished via fundamental mathematical models that can calculate the fire and sprinkler induced flows for different geometries. Such fundamental models are being developed at BFRL (NIST) by Drs. McGrattan and Baum. For experimental validation of these models, instantaneous field measurements are needed on the drop size distribution, drop velocity, sprinkler induced flows, fire induced flows and the actual delivered density resulting from the interaction of the sprinkler induced flows with the fire induced flows. This work attempts to provide some of these measurements. Measurements presented in this paper include planar optical measurements of: (a) Drop size distribution and droplet velocities produced by a scaled sprinkler head under various water flow rate conditions, and (b) The actual delivered water density at various heights from the sprinkler head (to provide an integral confirmation of the optical measurements). Sprinkler scaling relationships are also developed to relate the laboratory-scale & large-scale measurements.

EXPERIMENTS

Several axis-symmetric scaled pendent sprinkler heads were designed with different nozzle diameters [6, 8 & 10 mm] and different strike plate cone angles [90°, 120°, 140° & 180°]. These sprinklers were tested at different water flow rates [1 to 10 gpm]. A small nozzle diameter, high flow rate and a large strike plate angle is expected to create small droplets that will spread further from the center, whereas, a large nozzle diameter, low flow rate and a small strike plate angle will create large water droplets thatfall closer to the center. Thus, varying these parameters enables testing different sprinkler configurations. However, only some of these configurations could be contained within the 8'×8'×8' laboratory-scale experimental apparatus.

The flow rate and the pressure of the water to the sprinkler head is controlled by a valve and is continuously monitored. A red or yellow fluorescent dye (approx. 1 ppm concentration) is also introduced into the sprinkler water to enable filtering the scattered laser light and recording only the fluorescent emission from the droplets on to the photographs. This technique provides a more accurate drop size measurement by minimizing the "Gaussian ambiguity" and "ghost reflections". Furthermore, by appropriately choosing the fluorescent dye, two-color, double-exposed photographs are easily created. The dual Nd:Yag PIV laser is made to fire at the desired time intervals to measure the droplet velocity by the particle tracking technique. During these experiments, the water at the floor level is also collected tomeasure the actual delivered density.

High-resolution, large-scale planar [35cm×25cm] photographs taken during these experiments were digitized by a high resolution scanner. After digitization, the analysis was performed by the TSI INSIGHT software to determine the velocity vectors by the particle tracking technique The drop size distribution was determined by using the SCION IMAGE program. The measurements of drop size and velocity were made near the sprinkler head to help define the initial conditions needed for developing a sprinkler scaling criteria. This criteria is to tested by the measured delivered density.

The results are presented in figs. 1, 2 & 3. The origin of the graphs in figs. 1 and 2 correspond to the sprinkler location. Figure 1 shows the instantaneous droplet locations, whereas, fig. 2 shows the velocity vectors. As expected, the angle of the strike plate has a dominant influence on the droplet spread and the magnitudes of the droplet velocities are affected by the flow rates. The instantaneous drop size distribution determined from the photographs is shown in fig. 3. These are for the 8mm diameter nozzle and different strike plate cone angles. Clearly, the drop size distribution is not significantly altered by changing the strike plate cone angle. The data seems to imply that the drop size distribution is controlled by the sheet breakup process, the droplet spread by the strike plate cone angle, and the droplet velocities by the water flow rate for the same orifice diameter.

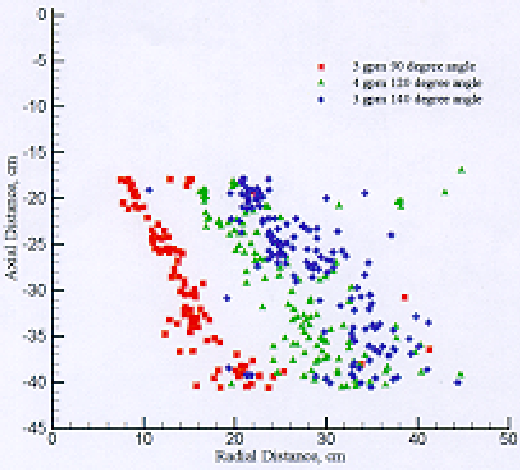

Figure 1. Drop Locations

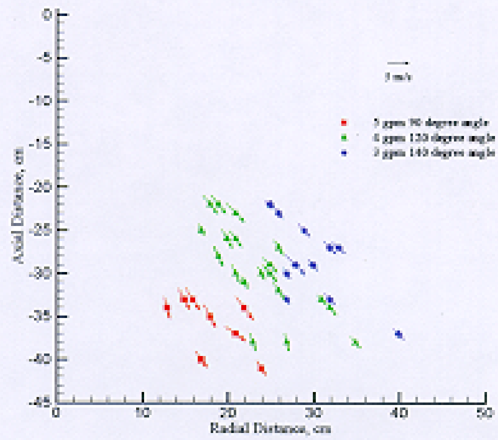

Figure 2. Drop Velocity Field

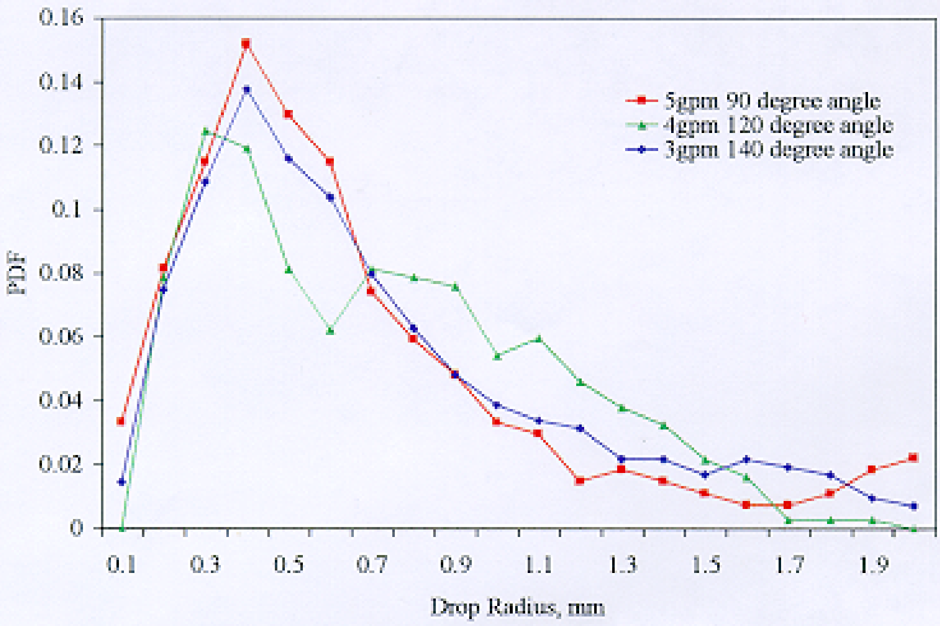

Figure 3. Drop Distributions Resulting from 8mm Nozzle